China's future energy consumption and emission pathways: Insights from soft-linking two global models

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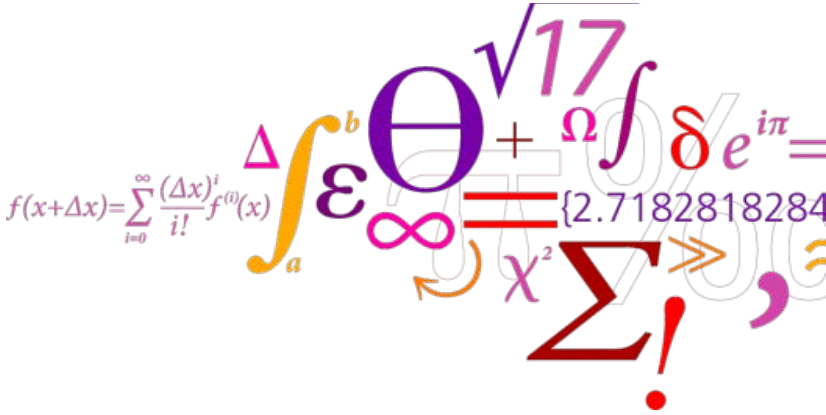

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Motivation and research interest

CHINA's RISE:

An improved understanding of plausible future pathways for China's economy and energy system is becoming more important to understand global energy markets, energy security, greenhouse gas emissions and environmental impacts.

DIFFERENT ECONOMIC DEVELOPMENT STAGES IN CHINA:

China's provinces are in very different stages of economic development today. Global energy models that account for regional economic and energy system differences within China do hardly exist.

CHINA-SPECIFIC GLOBAL MODEL LINKING FOR IMPROVED DECISION-MAKING:

We aim to soft-link two global models for an improved regional economy and energy system analysis of China's future energy policies.

Literature review – Linking models

- Böhringer 1998; 2008: macro-economic top-down (TD) and technological bottom-up (BU) models for assessing energy and climate policies.

- Hourcade, Jaccard et al. 2006: three categories of linking BU and TD models - soft-linking existing models; 2) focusing on one model type with a simplified representation of the other; 3) hard-linking

- Fortes, Simões et al. 2013: Linking CGE and TIMES model for Portugal

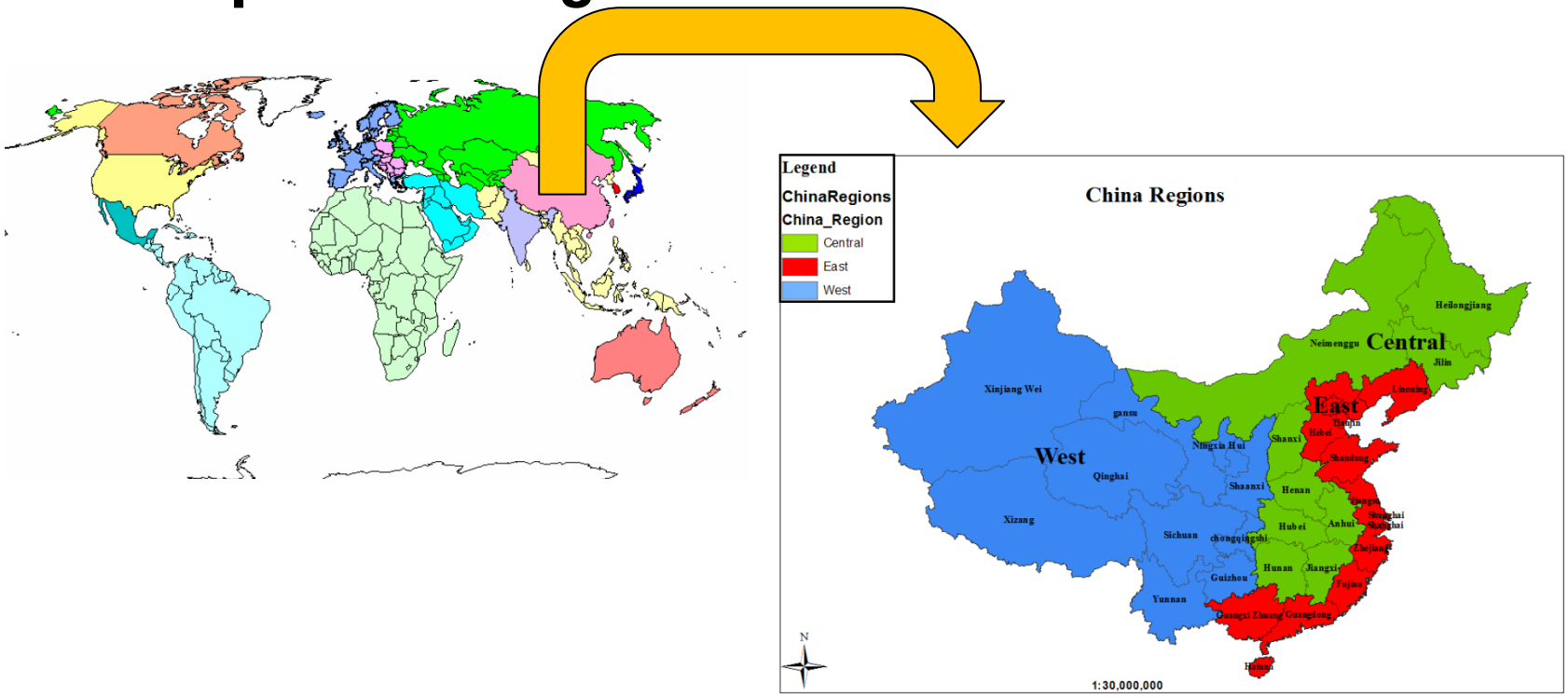
- Riekkola et al (2013): soft-linking a CGE model with an energy system model of Sweden

- Dai, Mischke (2014, in press): Hardly any soft-linking of global bottom-up and top-down models for of China

Introducing the two China-specific global models

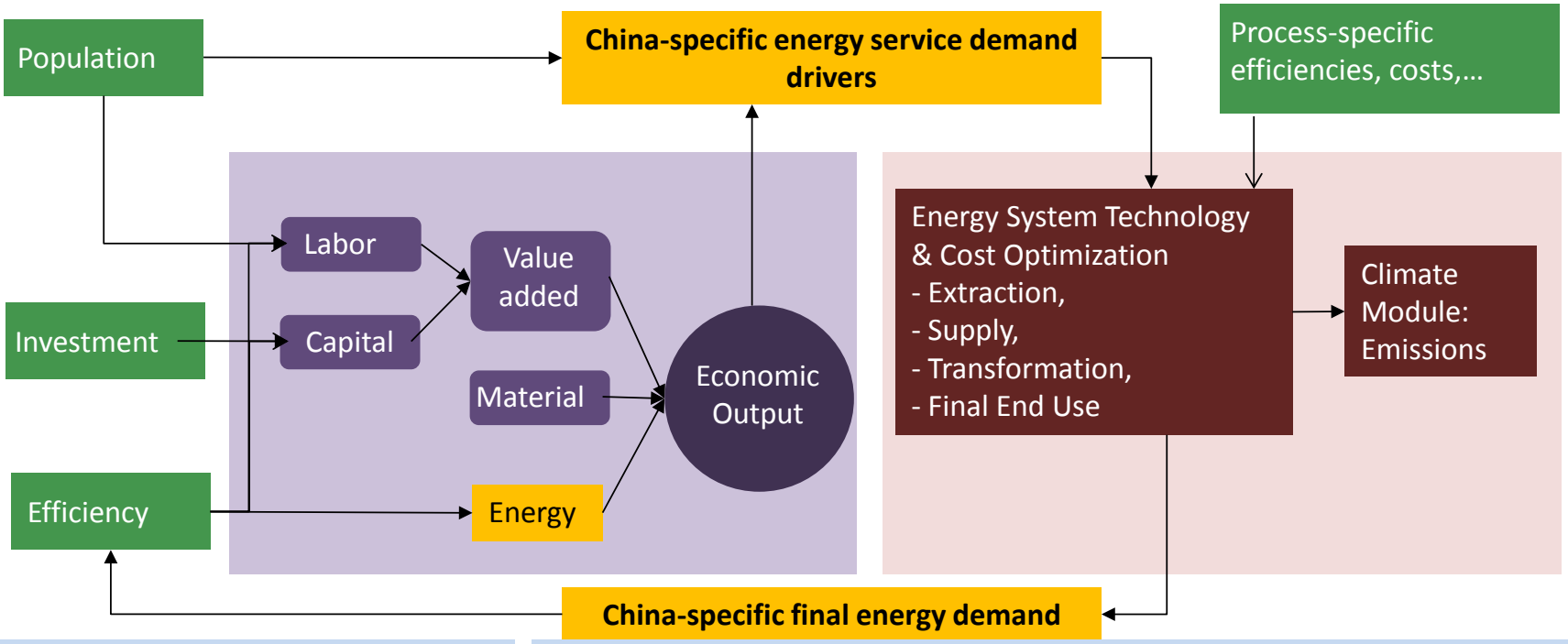
	Top-down CGE	Bottom-up TIAM
≠ Modelling approach:	general equilibrium model	Technology-rich linear optimization model
≠ Key inputs:	Population, Efficiency assumptions, future economic growth targets for China	Population, household, economy and energy service demand projections
≠ Key outputs:	Sectoral economic output, household income, GDP etc.	highly-detailed, cost-optimized energy use data
= Global Regions:	**15** (Africa, Australia-New Zealand, Canada, Central and South America, China, Eastern Europe, Former Soviet Union, India, Japan, Mexico, Middle-East, Other Developing Asia, South Korea, United States, and Western Europe)	
China Regions:	**30** provinces, municipalities, excl. Tibet	**3** (East, Central, West China)
Time horizon:	2002 - 2050	2005 - 2100
≠ Economic sectors:	22 economic sectors and 3 final demand sectors	energy resources/extraction, transformation and final energy use
Fuels and energy carriers:	Coal, Crude oil, petrol oil, manufactured gas, electricity	Coal, Crude oil, oil products, natural gas, electricity, heat, biomass, biofuels, ethanol/methanol, hydrogen, …
≠ Emissions and pollutants:	CO2, CO, NH3, NMVOC, CH4, N2O, NOx, SO2	CO2, N2O and CH4

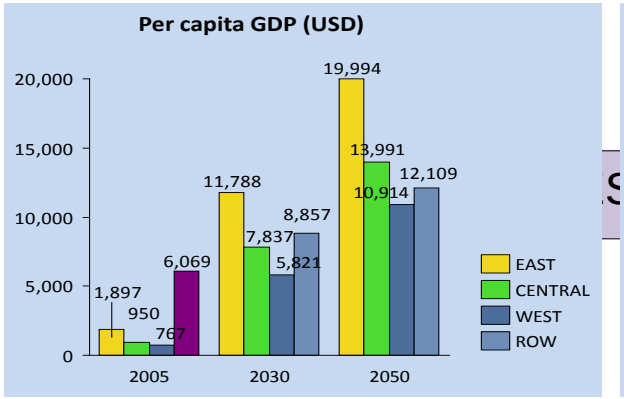
Soft-linking Methodology (II) – Global and China-specific regions

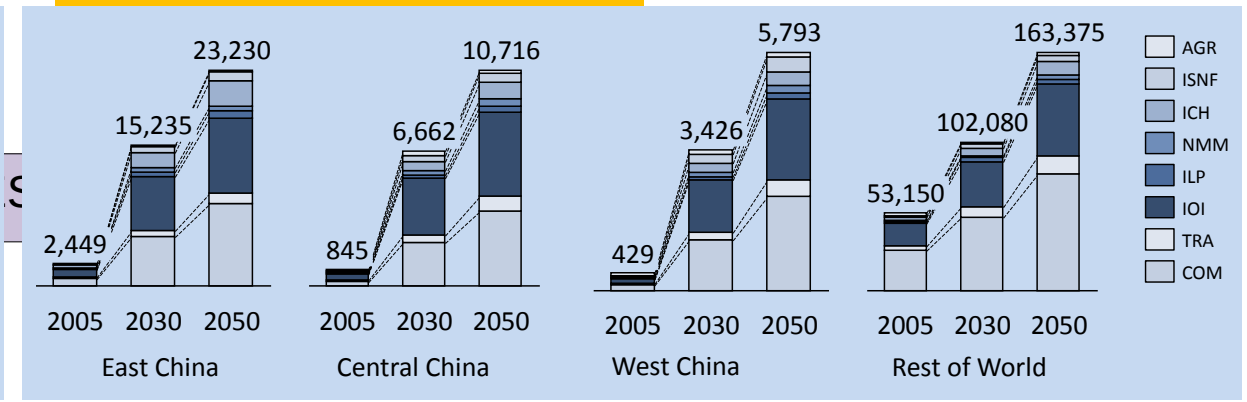


- East-, Central- and West-China + 15 regions in the rest world.
- The economic model can produce more detailed results within China, at the level of 30 provinces.

Soft-linking Methodology







Comparing models
Ref: coal use 2005-2050 (EJ)

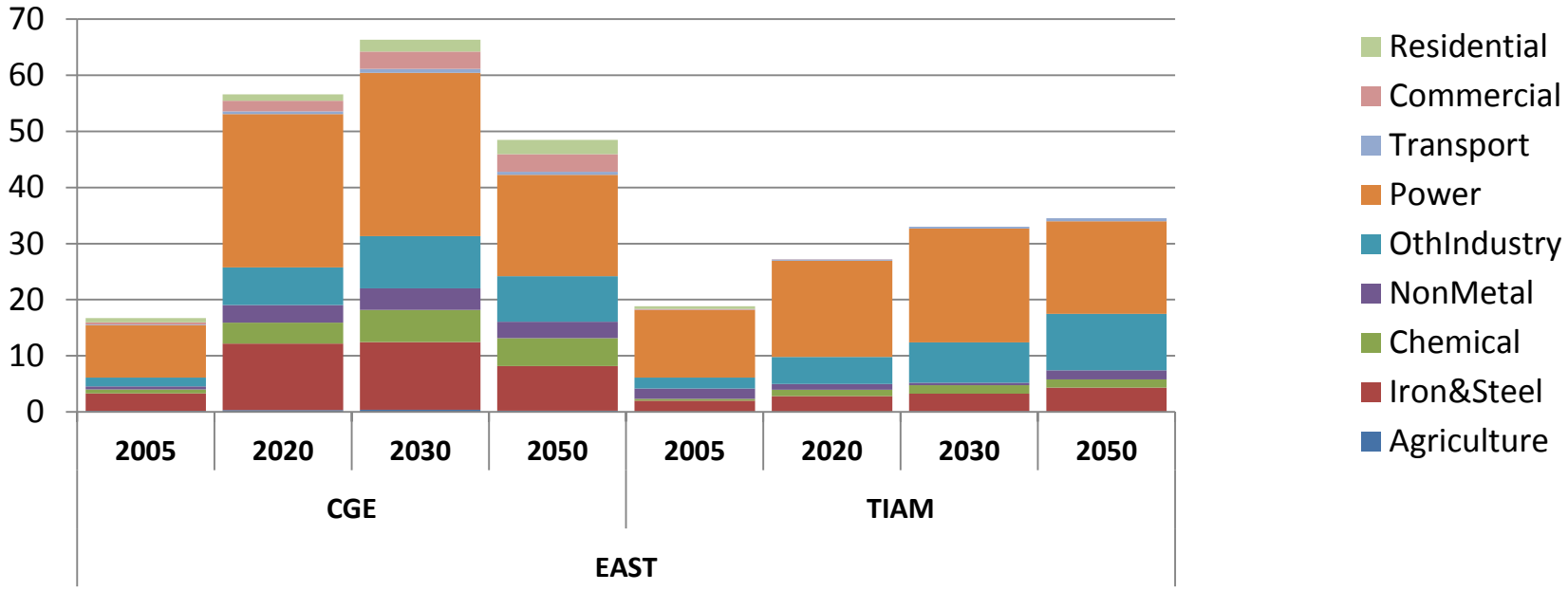
Agreement

Coal consumed for key sectors (power generation and other industries)

Disagreement

CGE: Higher total coal consumption in China; in sectors like iron, steel, non-ferrous metal, chemicals, non-metal production

TIAM: Higher total coal consumption in ROW



Comparing models
Ref: refined oil use 2005-2050 (EJ)

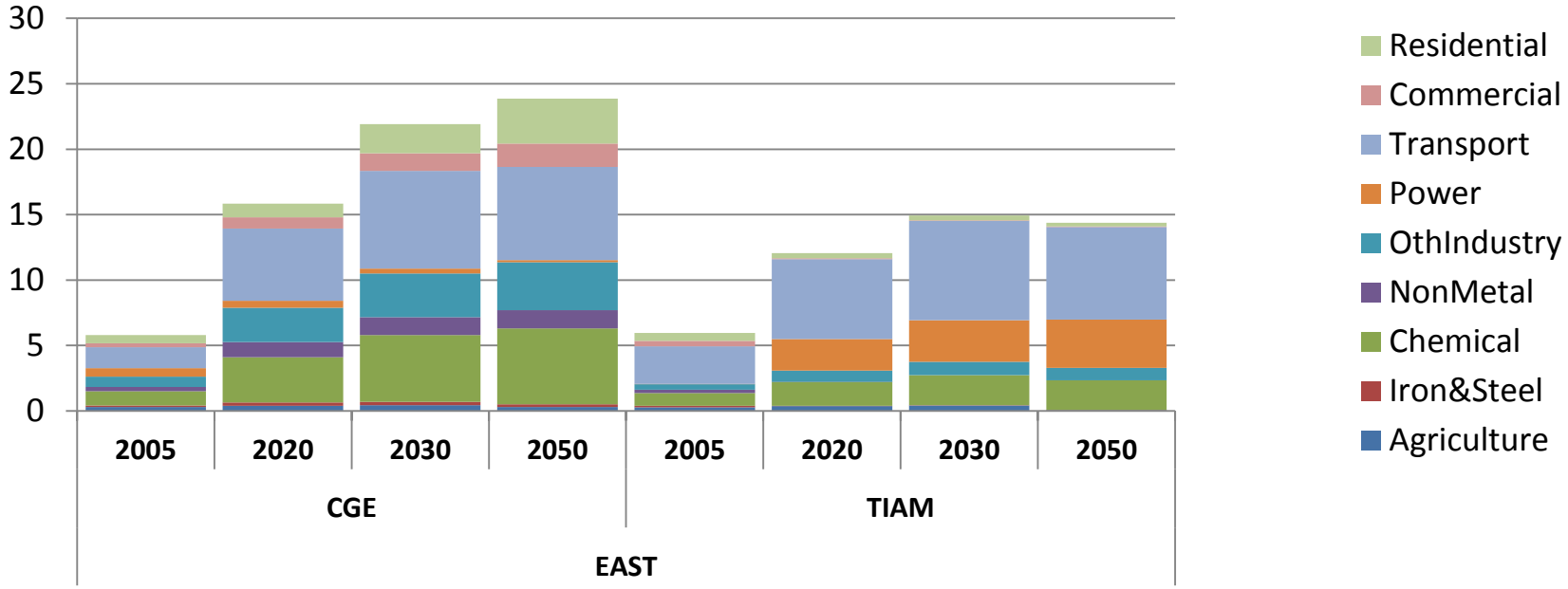
Agreement

Refined oil consumed for transport and chemistry sectors

Disagreement

CGE: More oil by transport and chemistry sectors

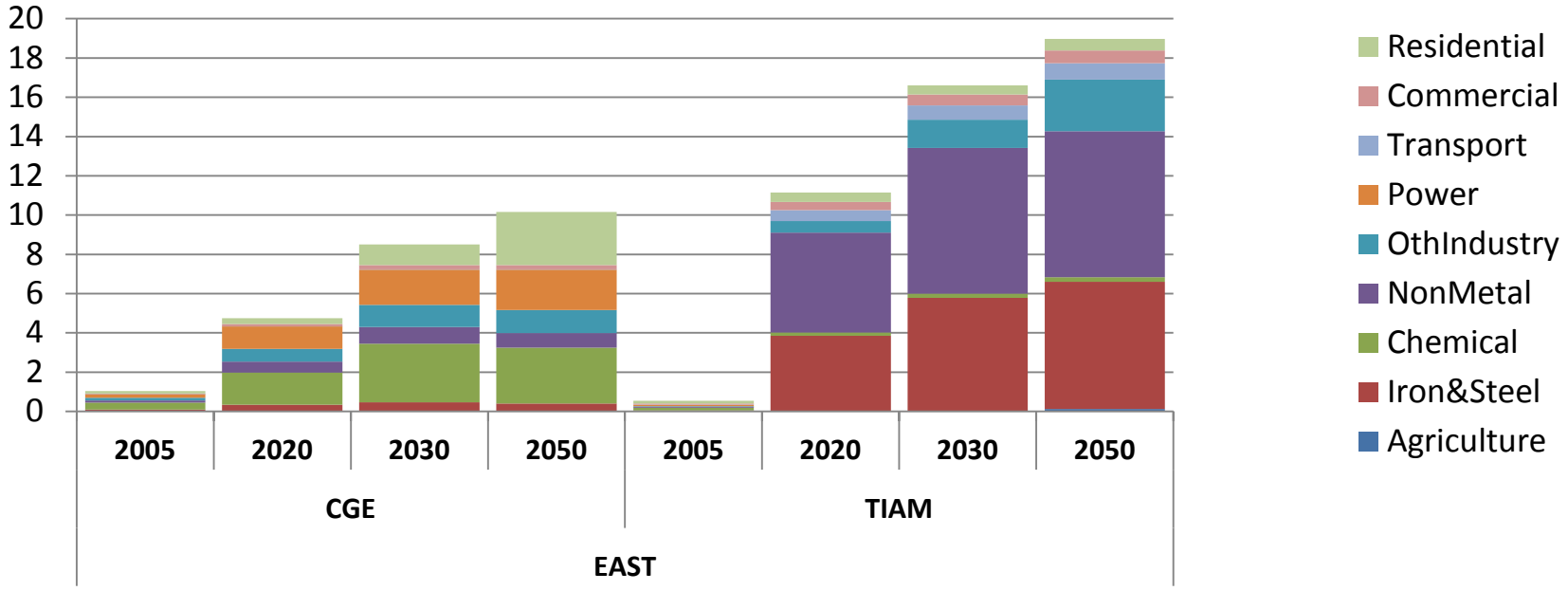
TIAM: More oil for power generation in east China;



Comparing models
Ref: gas use 2005-2050 (EJ)

Disagreement

More gas consumption in iron, steel and non-ferrous metal sector, non-metal production and other industries of all China regions in **TIAM**.



Comparing models
Ref: power use 2005-2050 (TWh)

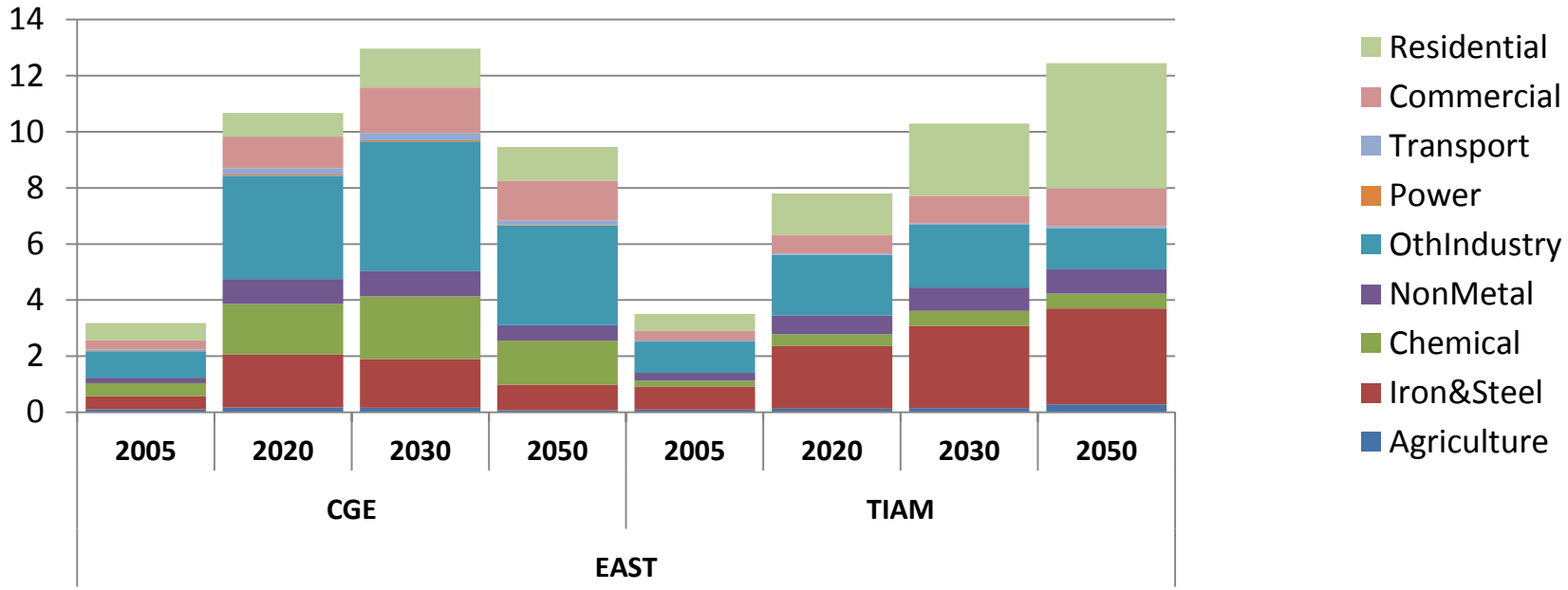
Agreement

Electricity consumption in 2030 and 2050 in China is relatively close between two models

Disagreement

CGE: More electricity by chemical and other industry sectors

TIAM: More electricity in iron and steel sector and household sector;



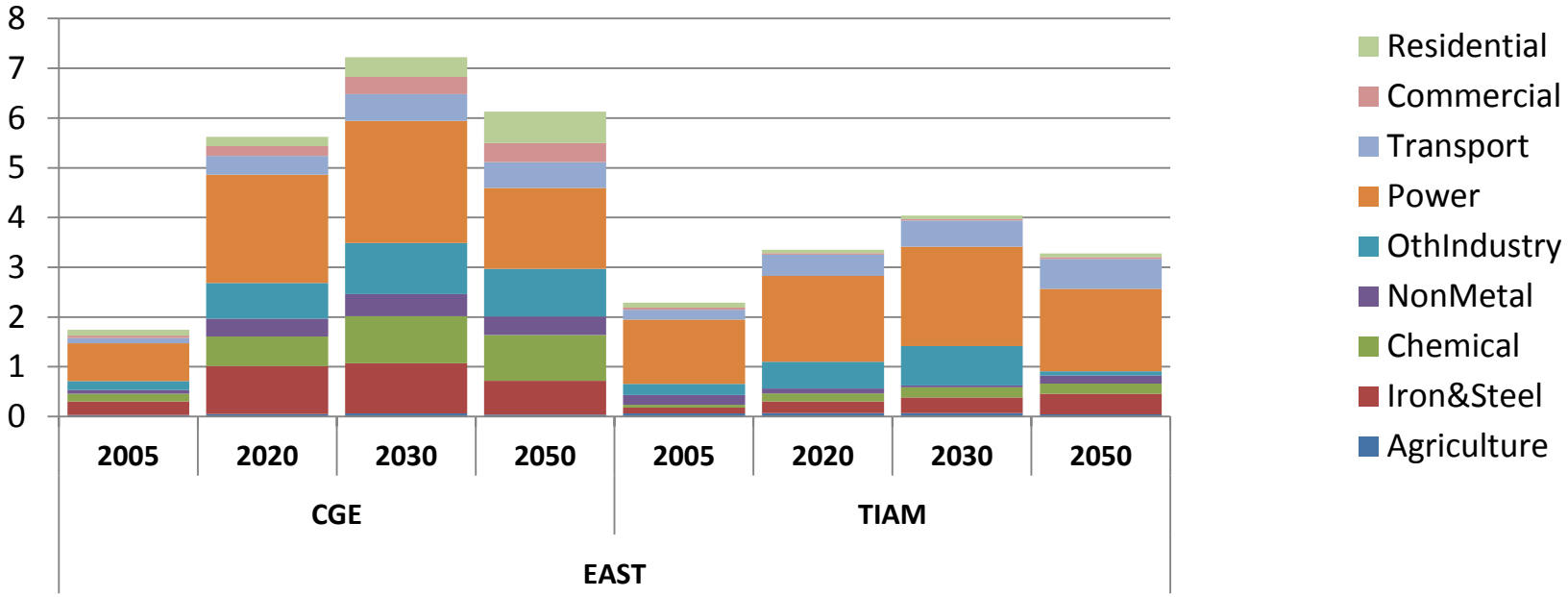
Comparing models
Ref: sectoral carbon emissions (GT)

Agreement

Sectoral CO_2 emissions peak between 2030 and 2050 in China.

Disagreement

The emissions from sectors other than power generation are different.



Reasons for disagreement

Technology representation:

- **TIAM**: explicitly represented → sudden changes according to technical lifetimes affect energy use
- **CGE**: implicitly incorporated in CES functions → smooth technology transition; no RE in power sector → coal use much higher

Underlying database:

- **CGE:** input-output table from China → transport sector only captures commercial transport but excludes private transport by household sector and transport service provided by other industries.
- **TIAM:** energy balance table from IEA → transport sector accounts both commercial and non-commercial transport services.

Emission accounting:

- **TIAM:** upstream, refining and fuel processing emissions not included in end use sectors.

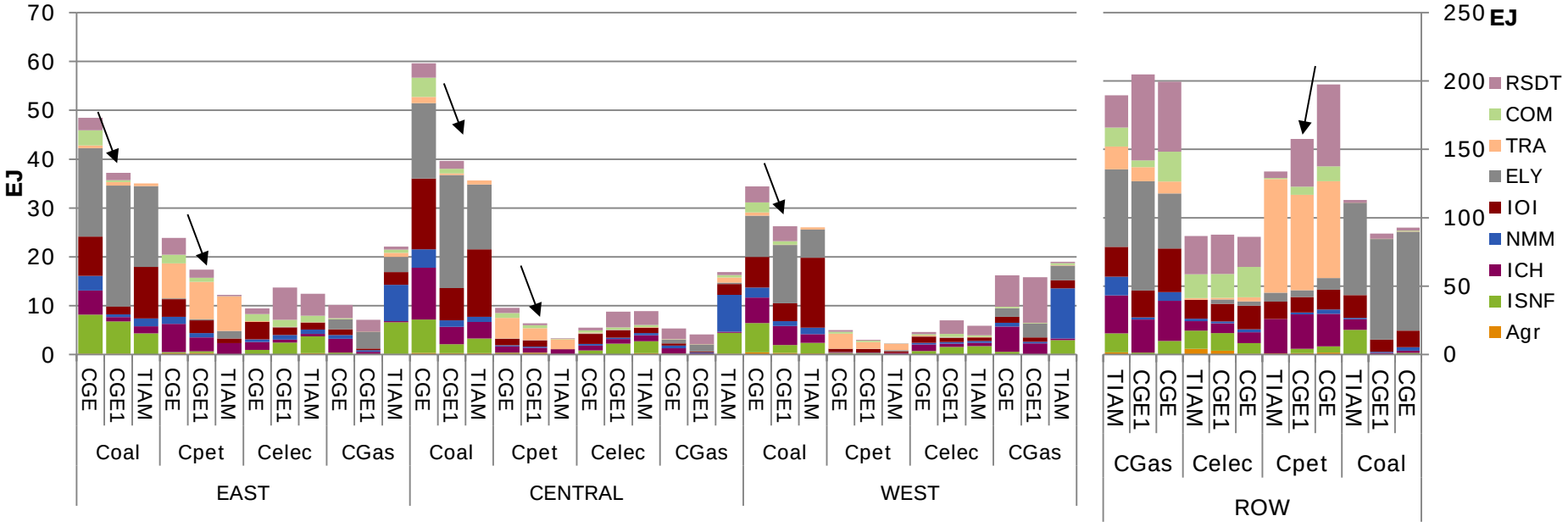
Modelling China's future energy policy goals:

- **CGE**: accounts for phasing out of oil use in power generation in the mid- and near-terms

Conclusion from soft-linking the models

- ✓ The first round iteration of soft-linking results in bridging the gap between the models for most total energy consumption indicators.
- ✓ Differences remain. The most important reason is that if energy efficiency parameters are changed, the production price of industrial products will change as well, consequently their demand will change.
- ✓ Policy recommendations for China could be based on different types of models. Soft-linking helps to understand differences in modelling approaches.

Energy consumption in 2050



Thank You! 谢谢!
Danke! Merci bcp! Gracias!

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